Retrieval of implicit inhibitory processes: The impact of visual field, object-identity and memory dynamics

Klaus Kessler[1] & Steven P. Tipper[2]
Heinrich-Heine-University Duesseldorf[1], University of Wales Bangor[2]

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Abstract

After exogenously cueing attention to a peripheral location, the return of attention and response to the location can be inhibited. We demonstrate that these inhibitory mechanisms of attention can be associated with objects and can be automatically and implicitly retrieved over relatively long periods. Furthermore, we also show that when face stimuli are associated with inhibition, the effect is more robust for faces presented in the left visual field. This effect can be even more spatially specific, where most robust inhibition is obtained for faces presented in the upper as compared to the lower visual field. Finally, it is revealed that the inhibition is associated with an object's identity, as inhibition moves with an object to a new location; and that the retrieved inhibition is only transiently present after retrieval.

Introduction

When searching the visual environment for an object it is essential that actions towards non-relevant objects are inhibited and that attention is continually moved to new candidate objects. If attention was to return continuously to previously examined objects, the target may never be found. Posner & Cohen (1984) proposed that inhibition was an essential mechanism to ensure that during search attention continued to move to novel loci. That is, after attention was withdrawn from a particular location, it was inhibited from returning.

Posner and Cohen (1984) provided empirical support for inhibitory mechanism of attention in a very simple and elegant procedure. Boxes were presented to the left and right of fixation within which targets could be presented. Prior to the targets one of the boxes could be cued (e.g., brightened) briefly. Participants were told to ignore this cue and to only respond to the target (e.g., an asterisk presented in one of the boxes). Such an exogenous cue was known to automatically trigger attentional orienting, probably via mid brain systems such as the superior colliculus (Posner Rafal, Choate, & Vaughan, 1985; Rafal, Calabresi, Brennan, & Sciolto, 1989). Shortly after the cue (100ms) detection of targets in the cued box was facilitated, presumably because attention was oriented to this site. However, at a later point in time (e.g., after 300ms) detection of targets at the cued box was inhibited.[1]

It was initially assumed that inhibition was associated with a location-based representation. That is, attention was inhibited from returning to a particular location. However, Tipper, Driver, and Weaver (1991) argued that the visuomotor system evolved to interact with objects in the world. That is, attention was moved around candidate objects, not randomly through space. Furthermore, it is possible to search for and act upon a moving object. Therefore they proposed that inhibition could be associated with object-based representations. This was confirmed in studies where, after cueing an object, the object moved to a new location before target presentation. The inhibition moved with the object. Further studies have shown that inhibition could in fact be associated with both location and object-based representations (Tipper, Weaver, Jerreat & Burak, 1994) and that the object-based effects could generalise to other paradigms (e.g. Behrmann, Zemel & Mozer, 1998; Egly, Driver & Rafal, 1994;

[1] There has been some debate as to whether inhibition is solely inhibition of spatial orienting of attention (inhibition of return- IOR) and/or is inhibition of responses evoked by the cue (e.g., Klein & Taylor, 1994). We acknowledge this point and note that this article does not distinguish between the spatial orienting or response aspects of inhibition. Rather, we are simply attempting to demonstrate retrieval of inhibitory states, and future work will be necessary to isolate the specific components of the retrieved inhibition.

Goldsmith, 1998; Humphreys & Ridoch, 1993; Tipper, Brehaut & Driver, 1990).

More recent work has shown that inhibition can in fact be associated with an object's identity in some circumstances (e.g., Tipper, Paul, Kessler, & Grison, unpublished). Such observations led to the somewhat radical suggestion that inhibition may in fact leave a long-term trace in memory. That is, during processing of an object, such as identifying a face, attentional states of the network could also be encoded. Thus, when the object was re-encountered at a later time, not only was recognition re-activated, but also the transient state of the attentional system was also briefly reinstated.

One might wonder why a system encoding long-term inhibitory effects would have evolved. We proposed that in many circumstances current visuomotor processes, such as searching for a target, are not always completed. The example we used to illustrate this point is as follows: Imagine you are searching your kitchen for a mislaid knife. After examining and preventing response towards a couple of potential objects the doorbell rings and you leave the kitchen to greet guests. Upon returning to the kitchen a few minutes later, how is search for the target resumed? We proposed two mechanisms: First, explicit recall of what you were looking for, and second, an implicit mechanism that reactivates the prior state of the attentional network as the environment provides retrieval cues. That is, inhibition of previously examined objects is reinstated, guiding search to new places. It is probably the case that it is such implicit retrieval that guides and supports explicit awareness. That is, eye movements have already started away from previously examined objects, and this aids conscious retrieval of what was to be found.

Tipper, Grison, and Kessler (2003) demonstrated that such long-term retrieval of prior inhibitory processing could be possible. It was important in these studies that attention was oriented to complex and rich stimuli that participants had not encountered before. Therefore they presented coloured images of faces which humans process extremely efficiently (e.g. Farah et al., 1998). This was necessary so that specific instances could be efficiently encoded into memory. In these studies face processing was implicit in that the goal of participants (to be described in more detail later) was to detect a green target stimulus presented over one of the faces.

There is indeed extensive evidence for automatic/implicit processing of faces (e.g., Chritchley

et al, 2000; Caquil, Edmonds, & Taylor, 2000; Lavi, Ro, & Russell, in press; White, 1995). It has been demonstrated that face processing can take place even though faces are ignored. For example, Liu and Kanwisher (2000) showed that in a MEG study, even when ignoring a face there was a significant N170 signal (see also Cauquil, Edmonds, & Taylor, 2000; Eimer, 2000). Of most relevance to our studies, Downing and Kanwisher (2000) developed a procedure that is similar to that discussed in this article. Participants were required to report the orientation of an oval shape that could be superimposed over a face that could be to the left or right of fixation. They observed significant activation in the Fusiform Face Area (FFA) even though the face was irrelevant to the task. Furthermore, there were significant signals to faces on the opposite side of the oval target. This also suggests that both cued and uncued faces are encoded, though the cued face may receive somewhat more activation.

Hence we employed face stimuli in our studies. Furthermore, the cue and target stimuli were specifically designed to encourage integration with the background face. That is, the red cues and green targets were semi transparent. Thus the faces on which they were presented remained visible and appeared to briefly turn red or green. As in Posner and Cohen's (1984) original procedure, participants were required to ignore and inhibit response to sudden onset red cues presented in the periphery. Such a cue triggers rapid orienting of attention and then subsequent inhibition of the cued object. At a later time the same face display was presented and participants were required to localize a green target presented over one of the faces. If the target appeared on the face that had previously been cued, inhibition would be revealed by slower reaction times (RT) as compared to detection of targets on uncued faces.

Via such a technique we hypothesised that the inhibition evoked by the red cue would be integrated with the face stimulus, hence modulating later processing. Indeed, Tipper et al (2003) demonstrated that after cueing attention to these complex and rich stimuli, when these stimuli were re-presented, detection of targets to the cued face was slower, even though up to 13 minutes and 96 intervening displays had been presented between cue and subsequent target.

Importantly, although retrieval of prior processing may seem surprising to many researchers who implicitly assume attentional processes such as inhibition are transient, other research has confirmed such effects. For example, Deschepper and Treisman (1998) demonstrated that the inhibitory processes acting on distractors to enable selection of a target (as revealed via

negative priming effects) could be observed with long delays between prime and probe displays. We have argued elsewhere (e.g., Houghton & Tipper, 1994; Milliken Tipper**,** Houghton, & Lupianez, 2000) that similar processes mediate the inhibitory effects observed via cueing (e.g., IOR) and priming (e.g., negative priming). Therefore one might predict that retrieval of prior inhibitory states might be observed in both procedures.

The current work is an attempt to confirm that long term inhibitory effects can be observed in cueing procedures. Furthermore, a number of properties of retrieved inhibition, such as visual field effects, object-based effects, and temporal properties of retrieval from memory, will also be investigated. These will be discussed shortly. However, the first issue we engage concerns whether the cueing episode is encoded into memory in a form that enables explicit retrieval of the cueing event. As noted above, face processing in the Tipper et al (2003) studies is incidental. The task is to locate green flashes presented on top of a face. The properties of the face, such as identity, age, sex are irrelevant. Nevertheless we have evidence that the inhibition evoked by the cue is integrated with the face stimulus. We predict that this encoding is not explicitly available, in that participants are unable to report whether a face was cued previously.

Thus in Experiment 1, after cueing trials where red cues (or green targets in 33% of the trials) are briefly presented over particular faces, subsequent target trials are presented. However, unlike previous experiments, green to-be-detected targets (or red to-be-ignored cues in 33% catch trials) are not presented. Rather the face displays are again re-presented, and participants are required to recall where the red cue (or green target) had been presented (they are not required to report colour).

There are three possible patterns of data that might emerge from this study: First, contrary to our assumptions, participants are consciously aware and can retrieve prior cueing states. Thus they will be above chance in reporting the face over which the red cue was presented. A similar pattern of data might also be observed even if participants are not consciously aware of the location of the cue, and we thank Tram Neill (personal communication, February 2004) for this suggestion. Thus, the cued face is encoded better than the uncued face because the cue attracted attention to the face, and hence this face is more familiar. Thus, in the current cue recall task it is possible that participants cannot consciously recollect where the cue had been presented, but because they are attempting to retrieve prior cueing, they will be biased

towards the stimulus that has a stronger representation, as it will appear to be more familiar. This account is important, because it has no recourse to inhibitory processing.

The second possible data pattern conforms to our assumption that participants are unable to explicitly recall where the red cue had been because they were never asked to undertake such a task, and they were ignoring it. However, implicit recall might not be involved either, so there should be no difference between cued and uncued faces. Finally, the third possible data pattern conforms to all of our assumptions. Thus, even though participants cannot explicitly report the location of the red cue, nevertheless, during encoding of the face display, prior inhibitory states are automatically reinstated. Such inhibition leads to the counterintuitive prediction that participants will be reporting more often the wrong location than the correct location of the cue. That is, if inhibition is reinstated - when encoding the faces, it will be slightly harder to respond to the previously cued face, hence biasing response to the uncued face.

Finally, it is not clear how well participants will be able to report the location of the previously overtly localized green targets. On the one hand, there is no requirement to attempt to encode into memory target location. On the other hand, the explicit encoding and response to the green target may support some later explicit memory.

Experiment 1

Methods

Participants. All participants were students at the University of Wales, Bangor and received course credits for their participation in the experiments. 15 females and 1 male participated in this experiment with a mean age of 20.4. All participants were right-handed.

Stimuli and apparatus. The stimuli in this experiment were the same 192 colour face photographs drawn from Art Explosion 250,000 (1995) CD-ROMs that were used in Experiment 1c of Tipper et al. (2003). These photographs were presented in 96 face displays where two faces were shown and where a male or a female face appeared equally often on the left and right side of the display. For each participant, a face display was presented twice (as cue & retrieval displays) in one of the conditions described below. As depicted in Figure 1, the two faces where always aligned along the horizontal midline of the screen.

The experiment was performed on an IBM-compatible personal computer with a Pentium II. Each face display was shown centred on a 19-inch superVGA monitor. A chin-rest was used to maintain a constant distance to the screen of 70 cm. From this distance each face stimulus had a visual angle of 9.0 degrees vertically and 6.0 degrees horizontally. The cue and target signals occurred 3.2 degrees towards the left and right of the screen (see Figure 1) on the average (there was a slight variation of the centre of the face in the pictures). The signal was a transparent red or green circle with a diameter of 2.9-degree. These red and green cues were superimposed over the face area. Because they were semi-transparent the face identity remained visible, and the face appeared to briefly turn red or green. E-Prime programming software (2001) was used to create the experiment, display stimuli, control timing, and log participants' keyboard responses.

(Figure 1 about here)

Design. Each participant had to process 96 trials showing a pair of faces, where each trial was comprised of one cueing and one retrieval display (therefore each face display was shown twice). In 64 of the cueing displays one of the two faces was cued with a red cue that required a 'no go' response corresponding to the 64 experimental cue displays in Tipper et al (2003). The remaining 32 cueing displays were green targets, requiring a spatial localization response. Finally, cues on the left and on the right face were shown equally often in the 96 cueing face displays. For the retrieval half of all trials the procedure was quite different (see Figure 1): Two faces were shown on the screen, one of which had previously had a red to-be-ignored cue or a to-be-localized green cue superimposed upon it. Participants were then required to report which face had the red or green cue superimposed upon it, they were not required to report the colour of the cue. In summary, the dependent variable in this experiment was the frequency distribution of the recalled cue location depending on the colour of the cue (red or green), on the side of the cue (left or right), and on the status of the recalled location with respect to the actual cue (was the cued location recalled or was the uncued location recalled).

Procedure. Participants sat before the monitor, with the keyboard in front of them, under dim lighting conditions. Each participant completed a practice session of 24 cue displays. Testing of the subsequent experimental trials lasted approximately 40 minutes. In the experiment, there were 192 total trials, 96 of which showed a face display and 96 of which showed a filler

scene display exactly paralleling the procedure of experiment 1c in Tipper et al. (2003). The participants first had to respond to the cueing half of the trials by pressing a key to localize the green cues while also inhibiting response to the irrelevant red cues. Presentation of a face display alternated with presentation of a filler display[2]. After self-initiating a trial, a central white fixation cross appeared for 300 ms, then the face display appeared for 1000 ms, one face was overlaid by the red or green cue for 200 ms, and finally the original face display was seen for a further 300 ms (see Figure 1). There were 1500 ms available for response from the onset of the cue signal. If one of the faces turned red, participants withheld response. If the left face turned green, they pressed the '4' key on the number pad with the left finger, whereas if the right face became green, they pressed the '6' key with the right finger. Before every face display participants were instructed to position both index fingers above these keys. This instruction was a graphics display showing a picture of fingers on particular key locations. After responding, participants received auditory feedback for a correct or incorrect response.

After a break of 3 minutes the retrieval half of the trials started with the same temporal order of the face displays. Therefore, each retrieval display followed the corresponding cue display after 12.6 minutes and 192 intervening face and filler displays (the delay between a cue and a retrieval display was also dependent on the time the participant needed to self-initiate each intervening trial, so 12.6 minutes is the group average). Note that it was at the beginning of the retrieval block, half-way through the experiment, when participants were informed that the same face displays will be shown once again and that they will have to report where the colour cue had been. During the initial cueing trials participants did not know that memory with respect to the faces was of any importance. In fact processing of the faces was not relevant at all for the cueing task, which was exactly the same procedure as in the Tipper et al (2003) experiments. In summary, particpants were presented with the same face displays in the same order again and had 1500 ms to report (guess) which one of the two faces had previously been cued.

Results & Discussion Experiment 1

In order to apply general linear model analysis relative frequencies were computed per

[2] In the cueing half we wanted to keep everything the same as in experiment 1c in Tipper et al. (2003) for highest comparability between our long-term IOR results and the results in the present report. While the goal of the filler tasks was to increase the possibility of finding long-term IOR with faces displays, they were not designed to detect long-term IOR in themselves because we did not cue episodically salient information.

participant and for green and red cues separately (as there were different a priori frequencies in the design). Figure 2 shows the group means and the standard errors.

A repeated measures ANOVA that included the factors "recalled position" (left/right) and "cue status" (cued/uncued) that was computed for red cues only, yielded a significant "cueing" effect ($F(1,15)=7.9$, $p<.015$) in that participants significantly recalled more often the uncued item. A repeated measures ANOVA for green cues that paralleled the one for red cues didn't show any significant effects.

(Figure 2 about here)

The results of the recall task are clear. Participants did not remember over which face the cue had been presented, but instead, were more likely to make an error and report that the red cue had been presented on the uncued face. This counter-intuitive result therefore provides support for our notion that prior inhibitory states are implicitly retrieved. The alternative explanation for the cueing effects, where the cued object is encoded more deeply due to attentional processing, is not supported. This is because this more familiar object would tend to be selected when attempting to recall cue location.

Interestingly, participants were also unable to report the location of the prior green targets. Although there was a trend for report of the cued location, this was far from significant. The green target required explicit/overt report of its location. This clearly did not activate an inhibitory state, but neither did it support explicit encoding that supported later retrieval. It is possible that the overall proportion of trials influenced the general processing state of the participant. Thus, the majority of trials were irrelevant to-be-ignored red cues. Therefore the processing context may have been that the colored stimuli presented over the faces were generally to be ignored, hence hampering explicit encoding.

Finally one other aspect of these results needs to be considered. The bias to report that the red cue had in fact been presented on the uncued face, was observed equally when the cue was superimposed over the left and right face. Note that this current study was based on that of Experiment 1c of Tipper et al (2003). Recall that in the latter experiment RT to detect a green target was the dependent measure. In this, and in fact in all RT studies so far, a clear hemisphere difference was observed. That is, the long term inhibitory cueing effect was only

significant when the red cue was superimposed over the left face. It is possible that the explicit recall measure of cue evoked inhibition employed in the second half of the present experiment, which biases response towards the uncued face in both visual fields, is a more sensitive measure than RT to detect green targets, because attention is directed to the faces themselves ("On top of which face was the colour cue?"), which in turn might influence quality of retrieval. In contrast, face processing remains implicit and automatic during the second ("target") half of our RT experiments. Thus RT effects can only be glimpsed when the most favourable conditions for automatic encoding and retrieving a face stimulus are available. That is, when the face is presented in the LVF. Furthermore, there is a non-significant trend in Figure 2 (Left) for faces on the left to be recalled more often than faces on the right. Hence, implicit inhibition might not be stronger in the right hemisphere, due to generally deeper face processing in the free recall procedure, yet the bias to recall faces in the left visual field might nevertheless reflect the hemisphere asymmetries underlying face processing.

The next experiment again examines the effects of to-be-ignored red cues via RT measures. In light of the symmetrical (left = right) cueing effects seen in Experiment 1, it is of interest to know whether the left and right sided bias initially observed by Tipper et al (2003) is again obtained.

Experiment 2

This second experiment was designed to confirm our prior observations reported in Tipper et al. (2003) and to engage a number of new issues, which involve visual field effects, object based inhibition, and memory dynamics. We are aware that the interactions between attention and episodic memory by means of encoding and retrieval processes are complex and hard to imagine in all details. A sketch of a model is therefore provided in Figure 4 which may serve as a guideline for the considerations that will follow.

First, Visual fields effects. As just noted, one interesting result in the Tipper et al (2003) studies was clear evidence for hemisphere differences. That is, long-term inhibition was only observed for faces presented to the left visual field (LVF). In contrast, faces presented to the RVF showed small non-significant trends for facilitation effects. Previous studies of inhibition evoked by peripheral cues (i.e., IOR) have also reported hemisphere differences when RT was the dependent measure (e.g., Berlucchi, Aglioti, & Tassinari, 1997; Handy,

Jhha, Kingstone, & Mangun, 1995; McDonald, Ward, & Kiehl, 1999; Nelson, Early, & Haller, 1993; White, Marks, & Wilkinson, 2001). These studies observed inhibition in both the left and right visual fields, but it was generally larger in the LVF. However the contrast between VFs is more dramatic when inhibition is retrieved from memory. In these studies inhibition is dependent on retrieval of prior object encoding, and such stimuli (e.g., faces) are known to reflect hemisphere differences. That is, faces are better processed in the right cortical hemisphere (e.g. Gilbert & Bakan, 1973; McCarthy et al., 1997; Rossion et al., 2000). Therefore, during initial encoding of the face and cueing of attention to it, and during subsequent retrieval of the face and the associated inhibitory state, performance was better for faces projecting to the more efficient right hemisphere.

Therefore, our first goal is to see whether such visual field contrasts can be replicated in a new set of experiments. This is particularly important in light of the symmetrical cueing effects found in Experiment 1.To preview our findings, generally we do confirm the visual field effects first reported by Tipper et al (2003) in that long-term inhibition was only observed in the LVF when RT to detect green targets was measured. However, we also investigated a second closely related issue. Previc (1990; Previc & Blume, 1993) has reviewed evidence showing different processing biases in upper and lower visual fields. Anatomically, the upper and lower visual fields project to different cortical areas. The upper visual field projects to the lower cortical sheets of V1 (e.g., Fellerman & van Essen, 1991; Gattass & Gross, 1981) and this in turn projects more to inferior temporal lobe (e.g., Maunsell & Newsome, 1987). In contrast, the lower visual field projects to upper cortical sheets in V1, and mostly to parietal areas. Therefore, one characterization of the upper and lower visual fields is that the former is more concerned with object recognition, while the latter lower visual field is more concerned with computations of perception-for-action (Previc, 1990). For example, visual search for targets is faster when they are in the upper visual field (Previc & Blume, 1993). Of particular pertinence in the current context, search for faces is faster in the upper visual field (Fecteau, Enns, & Kingstone, 2000). Furthermore, lesions to object recognition systems within inferior temporal lobe (IT) result in disturbed vision in the upper visual field (e.g., Damasio & Damasio, 1983) and poor recognition of upper visual field facial features (e.g., Gloning & Quatember, 1966).

We are aware of only one study that has previously investigated object-based inhibition in terms of upper and lower visual fields. van Schie (2002) demonstrated that inhibition-of-

return (IOR) associated with objects (line drawings) was twice as large in the upper as compared to the lower visual field. Importantly, and in sharp contrast, IOR associated with cued squares (as in the standard procedure) or associated with words, was equivalent in upper and lower fields. Such results suggest a clear role for object-based inhibition in the ventral visual stream, and clearly motivate our prediction that inhibition associated with faces will also be larger in the upper visual field.

The link between upper visual field and object recognition processes, particular processing of faces, clearly has implications for our studies of long-term inhibition that use face stimuli. Following Previc's (1990) analysis, it appears as if there has been a development of scanning, recognition and memory processes directed preferentially towards the upper visual field. Therefore it is possible that there may be biases in encoding and later retrieval of inhibition associated with faces in the upper visual field. Combining this with the clear left visual field bias we have already repeatedly observed, our predictions can be quite specific: Encoding and subsequent retrieval of long-term inhibition when face stimuli are cued will be most efficient when faces are presented to the left and upper visual fields: That is, the upper-left quadrant of the computer display.

Second, Object-identity effects. The demonstration of long-term retrieval of prior inhibitory processes in our previous work implies that object identity was associated with inhibition. This is because over many trials cues and targets were presented to the same location on the computer screen. Therefore retrieval of inhibition cannot be based on location-based frames. Rather, retrieval of specific face identity must be necessary. If it is indeed the case that inhibition is associated with the identity of the face, then it should be possible to observe long-term inhibition even if the face changes location between initial cueing and subsequent presentation (see Figure 3).

Therefore, similar to our previous work on short-term IOR (e.g., Tipper et al, 1991; Tipper, Jordan & Weaver, 1999) inhibition will move with the object with which it is associated. However, it should be noted that in the situation where faces are presented in different loci between cueing and retrieval displays, retrieval is expected to be less efficient. When the faces are in new loci, there is a less complete match between past (cueing) and present (retrieval) displays (Figure 3, Panel B). This less complete match between past and present may result in slower retrieval processes (Figure 4, Panel C). This idea links directly to our

last issue concerning the time course of inhibition retrieval.

(Figure 3 about here)

Third, Memory dynamics. To reiterate. We propose that after presentation of a to-be-ignored peripheral/exogenous cue, the cued object is associated with inhibition. We have been attempting to demonstrate that this inhibitory state can be encoded with an object's representation into long-term/episodic memory (Figure 4, Panel A). Importantly the inhibition is transient. After decay there is no active memory for prior processing such as inhibition (Figure 4, Panel B) until appropriate retrieval cues are presented (Figure 4, Panel C). When the object is re-encountered, the inhibition is transiently reinstated. Thus upon being exposed to a face again, retrieval of the face identity and the inhibition associated with it, impairs target detection (Figure 4, Panel D).

However, we predict that this retrieved inhibitory state is weaker than the inhibition during the actual event of initial cueing: In the standard cueing procedure there are no intervening events between cue and subsequent target, and hence the inhibition appears to be observable for a few seconds. Furthermore, as noted above, inhibition is encoded in multiple frames-of-reference, such as location- and object-based (e.g., Tipper, et al, 1994), this also will support its stability. In contrast, we hypothesise that retrieved inhibition will be much more fragile and transient. First, memory never allows for 100% recovery of an encoded event in all its facets. And second, inhibition retrieved from memory is only associated with the object-based frame of reference. Hence, the retrieved inhibition is transient, as the attentional networks guiding visuomotor processes move to new states (see Figure 4, Panel D).

Now consider the situation where exactly the same display is presented during cueing (Figure 4, Panel A) and later when targets are presented (Figure 4, Panel C1) . Efficient and rapid retrieval should be produced because all retrieval cues are available. In our previous work we presented faces for 500ms before target presentation and observed long-term inhibition. However, we also predict that if the faces are presented for longer before target presentation (e.g., Stimulus onset asynchrony –SOA = 1000ms), it is possible that inhibition will have decayed and hence less robust inhibition will be observed (see Figure 4, Panel D). Note that inhibition might decay within one second only for the long-term retrieval case, because storage of an episode is always subject to a certain loss of information (e.g. Tulving, 1972).

Our decision to take 1000ms for the "long" pre-target face display (retrieval cue) might seem somewhat arbitrary, but we could only rely on our previous research as a guideline (Tipper et al., 2003). Doubling the original presentation time of 500ms is therefore a reasonable first attempt.

Now consider the situation where the faces in the cue display (Figure 4, Panel A) and those in the subsequent target array are presented in different loci (Figure 4, Panel C2). Retrieval cues are now less efficient. The change in location between encoding and retrieval means that retrieval can only be achieved via identity, as the complete processing episode is not re-presented. Therefore retrieval will be slower. In this situation we now predict that inhibition will be revealed with longer (SOA = 1000ms) retrieval times than with shorter (SOA = 500ms) retrieval times (see Figure 4, Panel D).

(Figure 4 about here)

In summary: We present an experiment, which attempts to provide answers to three issues. We manipulate which quadrant (top-left, bottom-left, top-right, bottom-right) faces are presented in. Across the entire study we expect an interaction between left vs. right visual field and cueing, replicating our previous observations of more robust long-term inhibition when faces are presented in the left visual field. Furthermore, analysis of static displays will test whether long-term inhibition is even more spatially specific, being most robust in the upper-left visual field.

We also manipulate whether faces are in the same or different loci during initial encoding and subsequent retrieval. If the effect is object-based, then it should still be obtained when the faces appear in different places. Finally we manipulate the time between face and target onset during retrieval. We expect a three-way interaction between retrieval time (500ms and 1000ms) with inhibition effects (cueing) and static/moving displays. Put simply: When retrieval is fast with static displays, retrieval of transient inhibition should be more efficient with brief face target stimulus onset asynchronies (SOA = 500ms) than with longer SOA intervals of 1000ms. However, if retrieval is slower, i.e. when faces have changed location, then better retrieval of inhibition should be found with longer SOA intervals between face and target onset of 1000ms than shorter intervals of 500ms (see Figure 4, Panels C &D).

Methods

Participants. In the experiment 32 Psychology undergraduates from the University of Wales, Bangor, received course credit for their assistance. The participants were 12 males and 20 females, between 17 to 34 years of age, with an average age of 21,4 years. All participants demonstrated normal visual acuity, stereopsis, colour vision and were right-handed.

Stimuli and apparatus. The stimuli in each experiment were 640 colour face photographs drawn from Art Explosion 250,000 (1995) CD-ROMs. These photographs were presented in 320 face displays where two faces were shown and where a male or a female face appeared equally often on the left and right side of the display. For each participant, a face display was presented twice (as cue & target displays) in one of the conditions described below. As depicted in Figure 3, the two faces where always aligned along the diagonal of the screen, meaning that a display could be either composed of a top left and bottom right face or of a bottom left and a top right face.

The experiment was performed on an IBM-compatible personal computer with a Pentium II. Each face display was shown centred on a 19-inch superVGA monitor. A chin-rest was used to maintain a constant distance to the screen of 70 cm. From this distance each face stimulus had a visual angle of 5.4 degrees vertically and 4.4 degrees horizontally. The cue and target signals occurred 4.1 degrees on the average (there was a slight variation of the centre of the face in the pictures) towards the corners of the screen (see Figure 5). The signal was a transparent red or green circle with a diameter of 2.1-degree, where a red mask was the cue signal and a green mask was the target. Because the colour signals were semi-transparent the face identity remained visible, and the face appeared to briefly turn red or green. E-Prime programming software (2001) was used to create the experiment, display stimuli, control timing, and log participants' keyboard responses.

(Figure 5 about here)

Design. Each participant had to process 320 trials showing a pair of faces, where each trial was comprised of one cue and one target display (therefore each face display was shown twice). 256 of these were cueing trials, where red cues required a 'no go' response and subsequent green targets required a 'go' response. The remaining 64 trials were catch trials, where the initial cue displays required a 'go' response and subsequent target displays required a 'no go' response. These Catch trials were included to reduce the predictability of the cue-

target relationship.

The 256 cueing trials were equally drawn from a 2 x 2 x 2 x 2 repeated measures design (cue-target validity: [uncued/cued] x target location horizontal: [left/right]) x target location vertical: [top/bottom] x face motion [static/moving]). The latter variable tested whether long-term inhibition was object-based. In half of the trials faces changed their locations from cue to target within visual hemi-field (faces were always moving from top to bottom or vice versa) in order to test our second prediction that long-term inhibition is primarily based on object identity. In all trials either both faces were moved or they remained in the same loci in cue and subsequent target displays (see Figure 3). There were equal amounts of static and moving displays as well as equal amounts of each of the directions of movement.

As well as these within-participant design factors we included a between groups factor (16 participants in each group) that was aimed at testing our third hypothesis concerning the dynamics of long-term inhibition. More precisely, although the cue face display was identical in each group, we varied the presentation time of the face prior to target presentation (see Figure 5) [3]. Replicating Tipper et al (2003) we expected that when faces in the cue and subsequent target displays were presented in exactly the same location, retrieval of prior inhibitory processes would be relatively fast because of the match between encoding and retrieval displays. Therefore inhibition should be observed when the target face was viewed for 500ms prior to presentation of the to-be-detected target stimulus, as in our previous work. In contrast, faces in a moving spatial configuration, where cue and target face displays were presented in different quadrants, should be a worse memory trigger resulting in slower retrieval with a later peak of inhibition (Figure 4, Panel C2). Therefore we tested a second group of participants, where the target face was presented for 1000ms before the to-be-detected target. Apart from this change in display duration both groups had exactly the same

[3] One might wonder why we chose to include "target face presentation time" as a 'between participants' factor. There are in fact two reasons. First, it is often observed that with varying SOAs participants are likely to generate expectancies resulting in longer RTs to the shortest, and shortest RTs to the longest SOA. Such expectancies could easily overwrite the somewhat subtle memory effects under investigation. Second, due to the much more complex design than in the Tipper et al experiments we already had to increase the number of trials to the limit. Having "target face presentation time" as an additional 'within' factor would have doubled this number one more time. Clearly, surpassing a critical number of trials might affect the cognitive processes under investigation and hence undermine the comparison to our previous results. Thus, including "target face presentation time" as a 'between' factor was the optimal way to account for all constraints.

conditions and stimuli.

For each of the experimental conditions, in half of the trials the target appeared on a face that was not previously cued (i.e., uncued), while in half the target appeared on a face that was previously cued (i.e., cued). An inhibition effect was defined to be present if reaction times in the cued trials were significantly slower than reaction times in the uncued trials.

Procedure. Participants sat before the monitor, with the keyboard in front of them, under dim lighting conditions. Each participant completed a practice session of 24 cue displays followed by 24 target displays. Testing of the subsequent experimental trials lasted approximately 60 minutes. After self-initiating a trial, a central white fixation cross appeared for 300ms, then the face display appeared for 1000ms, one face was overlaid by the cue signal for 200ms, and finally the original face display was seen for a further 300 msec (see Figure 5). There was 1000ms available for response from the onset of the cue signal. If one of the faces turned red, participants withheld response. If one of the faces turned green then participants were required to press the corresponding key. In these cueing displays 256 of the trials were red cues to-be-ignored, and 64 were green targets to-be-detected (catch trials).

On each trial there were two possible response keys corresponding to the positions of the two faces. Before every trial participants were instructed to position both index fingers above these keys. This instruction was a graphics display showing a picture of fingers on particular key locations depending upon the position of the up coming faces. As pointed out earlier, faces could be either at the top left and bottom right, as in Figure 3, or at the bottom left and top right. Before every trial participants were told where to expect the faces and where to position their fingers in order to press the key if the corresponding face turned green: On the top left/ bottom right trials they pressed the '7' key on the number pad with the left index finger if the top left face turned green, and they pressed the '3' key with the right index finger if the bottom right face became green. On the bottom left/ top right trials they pressed the '1' key on the number pad with the left index finger if the bottom left face turned green, and they pressed the '9' key with the right index finger if the top right face became green.

After responding, participants received auditory feedback for a correct or incorrect response. The target followed the cue after 4.3 minutes and 80 intervening face displays (note that the delay between a cue and a target also depends on the time the participant needs to self-initiate

each intervening trial, so 4.3 minutes is the group average). After a block of 80 cue trials, there was a 20 second break before the matched block of target trials was presented. These target displays were the same faces in the same order as viewed in cue trials. In one group of participants these subsequent target faces were presented for 500ms before the target, and in the other group they were presented for 1000ms. There were 4 sets of such paired cue block and subsequent target block of trials.

Results & Discussion Experiment 2

The data from the catch trials were not analysed. Target detection RT data were analysed in a 5 way mixed design analyses of variances (ANOVA) in a 2 x 2 x 2 x 2 x 2 design. The within-participants factors were: cue-target validity: [uncued/cued], target location horizontal: [left/right]), target location vertical: [top/bottom], and face motion [static/moving]). The between participants factor was face display time prior to target presentation (500/1000ms). Mean target RTs and standard deviations are shown in Table 1. All inferential tests used a significance level of $p<.05$.

Clearly this study is an extremely complex design. Therefore we focus our main analysis on the critical cue-target validity factor that reveals inhibition effects in an attempt to provide answers to our three critical issues (visual field effects, identity-based inhibition, and time-course of retrieval). A variety of other main effects and interactions emerged from the 5-way ANOVA, and these are presented in Appendix A for the interested reader.

Over-all RT Results concerning inhibition

As a first result regarding our investigations of the retrieval of inhibitory states we obtained an almost significant main effect of cue-target validity, cued trials being slower than uncued trials, $F(1,30)=4.02$, $p<.054$, showing a tendency for an over-all inhibition effect of about –4ms (uncued-cued trials RT). However the effect of cue-target validity was modulated by horizontal target location, as suggested by a significant interaction of the two factors, $F(1,30)=13.7$, $p<.001$. This was mainly due to the fact that significant inhibition of -8.3ms showed up only in the left visual field ($F(1,30)=17.7$, $p<.001$). Therefore this provides an answer to our first issue: A clear replication of the Tipper et al (2003) RT data, where inhibition is only significant in the LVF.

(Table 1 about here)

Our predictions concerning the dynamics of long-term inhibition are supported by a three-way interaction (Figure 6) of cue-target validity (cued/uncued), face motion (static /move), and the duration of the retrieval cue (500/1000ms), $F(1,30)=9.9$, $p<.01$. As we predicted, when the cue and target displays are identical (static) retrieval of inhibition is fast and transient, being significant at 500ms ($F(1,30)=11.4$, $p<.01$) but not at 1000ms retrieval cue duration. In contrast, when retrieval cues are less efficient because cue and target faces are presented in different locations (move condition), the opposite pattern is observed with no inhibition at the short (500ms) but inhibition at the long duration (1000ms).

(Figure 6 about here)

Further analysis revealed a significant 4-way interaction between target validity (cued/uncued), vertical target location (top-bottom), face motion (static/rotate) and duration of the retrieval cue (500/1000ms), $F(1,30)=5.2$, $p<.05$, as shown in Figure 7. According to this interaction, inhibition was only retrieved in the upper visual field. This is significant in the static displays with a short (500ms) duration of target face retrieval ($F(1,30)=12.1$, $p<.01$); whereas with a long duration (1000 ms) inhibition is apparent only with moved faces, again in the upper hemi-field ($F(1,30)=7.5$, $p<.05$). This is exactly conforming to our hypotheses. First, the goodness of the retrieval cue (static vs. moving) indeed seems to play a major role in the dynamics of long-term inhibition. Second, the upper visual hemi-field seems to be sensitive to inhibitory face processing.

(Figure 7 about here)

RT Results for Static Face Configurations only.

In order to test more specifically our hypotheses about the impact of the four different display quadrants (top-left, top-right, bottom-left, bottom-right) we did an analysis of the static displays only. This was because in the moving displays visual quadrant is confounded by encoding of the cue and retrieval of the target displays. That is, because of the motion of face position between cue and target display, faces appear in all four quadrants. The settings for the ANOVA were the same as for the above analysis, apart from excluding face motion as a factor by having only the static configurations included.

(Figure 8 about here)

With respect to inhibition effects, the main effect of cue-target validity was significant ($F(1,30)=4.5$, $p<.05$). However, there was also a significant interaction between cue-target validity and duration of the retrieval cue ($F(1,30)=7.0$, $p<.05$): Inhibition associated with static faces (-10.8ms RT effect = uncued-cued trials) was transient, only being observed with 500ms SOA between the retrieval cue and the target, $F(1,30)=11.4$, $p<.01$. This provides a clear answer to question three: retrieval of prior inhibitory states can be fast (within 500ms) and transient (declining to +1.2ms after 1000ms). Finally, the interaction between target validity, vertical target location, and horizontal target location turned out to be significant, $F(1,30)=6.5$, $p<.05$ (see Fig. 8). Of most relevance here is that this interaction was mainly due to a significant amount of inhibition associated with faces in the top-left quadrant ($F(1,30)=14.6$, $p<.001$), whereas no significant effect of cueing validity could be observed for the other quadrants.

RT Results for Moved Face Configurations only.

For moved faces the interaction of cue-target validity with horizontal target location reaches significance, $F(1,30)=8.3$, $p<.01$, due to a significant amount of inhibition (-7.8ms) on the left ($F(1,30)=8.4$, $p<.01$) and a numerical positive cueing effect on the right (+4.2ms). Therefore this result provides answers to our first two questions: inhibition is observed only in the left and not the right visual field (cf Tipper et al, 2003); and second, inhibition is observed when the face moves within a visual field (top to bottom or vice versa) between cueing and target presentation. The latter result confirms that inhibition is object-based, moving with an object (e.g., Tipper et al, 1991, 1994, 1999).

General Discussion

This research has investigated interactions between attention processes and memory. The core idea is that attentional processes acting on a stimulus, such as inhibition, can be encoded with the stimulus into long term memory. When the stimulus is re-encountered at a later time, prior processing episodes are retrieved, which mediates object recognition. Importantly, we argue that prior attentional states such as inhibition can also be reinstated. Such retrieval of inhibition facilitates behaviour over time, such as reactivating a search process that might have been interrupted previously.

In this article we have investigated further properties of these interactions between attention

processes and memory. In the first experiment we examined whether the prior effects of cueing an object could be consciously retrieved. That is, at a later time, could participants recall over which object the cue had been presented? Aside from revealing important properties of these long term cueing effects, this study enabled us to test between two alternative accounts of the cueing effects. In one account, the cue orients attention to one of the faces which results in deeper encoding and hence increased familiarity. When the faces are re-presented at a later time, participants might tend to detect targets faster on top of the more novel, unfamiliar face. This would then be the uncued face. In a free recall task, however, familiarity would provide a hint regarding which of the faces was previously cued. Hence, in such a task, responses will be biased to the cued face, as it has a more robust representation and therefore appears more familiar.

In sharp contrast, implicit retrieval of prior inhibitory states predicts the opposite pattern. Thus, upon re-presentation of the faces, prior inhibitory states associated with the cued face are retrieved. This would then bias orienting to the uncued face. Therefore participants would be more likely to report that the cue had in fact been presented on the uncued face, and hence make a significant amount of errors. This counter-intuitive result was in fact observed, supporting the notion that prior inhibitory states can be retrieved from memory, but knowledge of prior cueing is encoded implicitly.

One other result of note emerged from Experiment 1, and this was somewhat unexpected. Recall that in our previous study (Tipper et al, 2003, Experiment 1C), upon which Experiment 1 was modelled, clear hemisphere differences had been observed. That is, when RT to report location of the green target was measured, the inhibition effect was only observed for faces in the left visual field (LVF). In contrast, the bias to report that cues had been presented on uncued faces in Experiment 1 was equivalent for faces in the left and right visual field, although there was a numerical trend to recall faces on the left more often. It is possible that the hemisphere effects observed in Tipper et al (2003) are not very robust and hence are not always replicated. On the other hand it might be the case that the two measures of prior cueing (memory recall and RT to detect targets) have different levels of sensitivity. Thus, the former memory/recall task might be more sensitive, due to deeper processing of the faces ("On top of which face was the colour cue?") while the RT measure (to green super-imposed targets) might only detect prior effects of cues when conditions are optimal for automatic face encoding and retrieval. Therefore optimal face processing in the LVF is because faces are

better encoded and retrieved when processed directly by the right hemisphere (e.g. Farah, 1990; Gilbert & Bakan, 1973; Kanwisher et al., 1997; McCarthy et al., 1997; Michel, Poncet & Signoret, 1989; Moscovitch, Winocur & Behrmann, 1997; Ricciardelli, Ro, & Driver, 2002). This in turn seems to be especially true if face stimuli are processed as wholes - like in our case - and not as parts (Rossion et al., 2000). The current work has replicated and extended this finding.

In our previous work (experiment 1a in Tipper et al., 2003) we observed only a small trend for visual field biases over the short term (1800ms SOA), although hemisphere differences in inhibition have been observed in other studies. However, the left-right visual field effects were much more dramatic and highly consistent when we examined the retrieval of inhibition over longer intervals. As noted previously, the long-term inhibition effects are reliant on retrieval of prior processing of objects. Thus any biases in the processing system that enable more efficient encoding and retrieval of a stimulus will aid the retrieval of the inhibitory attention/response states associated with the stimulus.

As reviewed above, there is clear evidence for biased face processing in the right cortical hemisphere. However, other structures involved in the encoding/retrieval aspects of Episodic Memory (EM) also show such biases. For example, Burgess (2002), Brewer et al. (1998), and Cansino et al. (2002), have argued that the hippocampus might be a physiological structure mediating episodic memory (EM). In line with this assumption O'Reilly, Braver and Cohen (1998) included a sub-network in their connectionist model that parallels the hippocampal structure and, most important, this sub-network learns new patterns, by "taking snapshots" of the entire activation pattern in the rest of the network and by storing them as episodes. Such "snapshots" could represent the state of attentional networks whilst encoding a stimulus. Concerning hemisphere differences, the right hippocampus seems to be more clearly involved in the encoding and retrieval of objects in a spatio-temporal context as shown, for example, by Smith & Milner (1981) with respect to patients with right hippocampal lesions and by Cansino et al. (2002) by means of fMRI.

Our new hypothesis concerning visual fields was that inhibitory states would be more easily retrieved in the upper than in the lower visual field. This was based on the work of Previc (1990; Previc & Blume, 1993) who proposed that upper fields projected more to the object recognition systems of the temporal lobe, while lower fields project to the vision-for-action

systems of the parietal lobe. Previous work has indeed shown that when objects are cued, inhibition is significantly larger in the upper visual field (van Schie, 2002); and that search for face stimuli is faster in the upper field (e.g., Fecteau et al, 2000). Such findings predict that inhibition in our studies should also be larger in the upper-field, and indeed this was confirmed. Analysis of the static displays enabled us to get an even clearer picture of these field effects. This showed that the long-term inhibition effects could be quite spatially specific, in that they were confined to the top-left quadrant, where upper and left biased effects combined. Recent research has also highlighted the importance of visual field effects (e.g., Handy, Grafton, Shroff, Ketay, & Gazzaniga, 2003). This work examined how the implicit recognition of an object's motor affordances biases visual attention. They observed field and quadrant biases, where significant effects were observed in the lower-right visual field for example, as predicted by the hypothesis of greater links between lower visual field and parietal cortex (Previc, 1990).

Concerning a possible explanation of these visual quadrant effects, one can assume that the visual field effects are mediated by a larger size and a higher specificity of the neural populations in the ventral stream of the right hemisphere dedicated to the processing of these face stimuli. It can be argued that this efficient encoding results in a higher salience of the stimulus in the respective physiological subsystems. However, it should be noted that these visual field effects need not be fixed and invariant. Although the efficiency of neural encoding may bias processing of one face over another, certain experimental contexts and procedures may reverse such biases, as demonstrated in Tipper et al (2003, Experiment 2).

The second issue engaged in Experiment 2 concerned whether the inhibition evoked by the cue was indeed associated with the face upon which it was superimposed. The demonstration of long-term inhibition in our previous work (Tipper et al., 2003) suggested that inhibition was primarily associated with object identity, because the location of the items didn't change over all the intervening trials between cue and target (48 intervening trials in experiment 1b and 96 in experiment 1c). Therefore retrieval is very unlikely to be based on location-based frames, because pure locations do not provide any discriminative information between two separate episodes. Rather, retrieval of specific face identity must be necessary.

Therefore our second hypothesis was that inhibition was identity-based. If it was indeed the case that inhibition was associated with the identity of the face, then it should have been

possible to observe long-term inhibition even with changed locations. This is precisely the result we obtained: Even if face locations are changed between cue and target we do get significant long-term inhibition in the left visual field and numerical facilitation in the right visual field, exactly replicating our previous RT results with static, horizontally aligned face stimuli (Tipper et al., 2003).

Although we have confirmatory results for our second hypothesis, it should nevertheless be noted that in the situation where faces are presented in different loci between cueing and retrieval displays, retrieval is expected to be less efficient. The spatial configuration of the faces on the screen is changed, so we postulated a less complete match between past (cueing) and present (target retrieval) displays. Less efficient and hence slower retrieval, combined with the idea that retrieved inhibitory states would be transient, led to our third hypothesis concerning memory dynamics.

As sketched out in Figure 4, we have been attempting to demonstrate how transient inhibitory states can be encoded with the representation of an object. In our view inhibition is exerted by activated units that have inhibitory connections to other units in a network (see Houghton & Tipper, 1994 for a connectionist implementation of such an account). These activated inhibitory units are part of the over-all pattern of active units that represent the entire object and they can therefore be part of the pattern encoded into episodic memory. If an appropriate retrieval cue enters the system then a pattern matching process is started automatically in the episodic memory module that results in a "recall" of the initial episode if a match can be established. Obviously this pattern matching procedure is essential for the success of retrieval. This might result in a complete mismatch with no episode being retrieved at all or in a slower retrieval process depending on the goodness of the retrieval cue. In our case we expected moved faces to slow down retrieval, but we didn't expect retrieval to be completely disrupted, because this would have contradicted hypothesis 2.

With a successful match, the initial episode is recalled, and the inhibition is therefore reinstated as well. Note that once the inhibitory units get re-activated, their activational state again decays transiently over time (Figure 4, Panel D). Additionally we assumed that during memory encoding/retrieval information always gets degraded to a certain extent, resulting, in our case, in less retrieved inhibition that will decay relatively rapidly. This transient inhibitory state after retrieval contrasts with inhibition at the time of cueing, which appears to

be more stable (e.g., Paul & Tipper, 2003). We therefore predicted that after retrieval, attention is more likely to briefly orient to the uncued face, but shortly after this, attention is likely to have moved to a new state. This should interact with the speed of retrieval in the following way: First, highly matched and thus rapid retrieval with static faces should produce an early peak of inhibition, but this should also be accompanied by an early decay of inhibition. Second, less matched and thus slower retrieval with moved faces should produce a later peak and a later decay of inhibition. Again, this is precisely the result we obtained.

The simplest possible architecture for such an episodic memory (EM) sub-network that takes "snapshots" as proposed by the O'Reilly et al model could be an auto-associative network as described by Rumelhart & McClelland (1986) in their early PDP work. Several other candidate architectures have been proposed since then, some of which are computationally more powerful (e.g., Pollack, 1990; Elman, 1990) and/or physiologically more plausible (e.g. O'Reilly et al. 1998; O'Reilly & Munakata, 2000). Our main concern here is to point out that episodic memory (EM) may work in a very simple but at the same time very general way. An auto-associative network is trained or designed to associate patterns to themselves, which in turn can be used to recover the entire pattern from a partial input of the initial pattern (Rumelhart & McClelland, 1986, p. 55). The less complete the input is, the longer the recovery process takes, or it may even fail (see Rumelhart & McClelland, 1982 for a letter recognition network as an example). These features make sense for a model of EM, because an already stored episode can be retrieved by having only a partial pattern of the initial episode as input (retrieval cue). Additionally, such a recovery process can easily account for our finding that the speed of episodic retrieval directly depends on the goodness (completeness) of the retrieval cue (cue and target faces in the same or different loci).

Thus we are actually postulating two sorts of dynamics. First, the time at which inhibition is retrieved will be determined by the match between encoding and retrieval states. Second, once retrieved, inhibition is relatively transient, as attention moves to new states. Both of these ideas are supported by the data: Good match between cue and target displays, where the face displays are identical, results in early appearing inhibition (500ms SOA) that is transient and not observed shortly afterwards (1000ms SOA). The opposite pattern of delayed retrieval of inhibition is observed when the cue and target do not exactly match, in that the face stimuli are presented in different loci.

In conclusion, our data clearly show that the retrieval of inhibitory states can be observed in certain circumstances, and that retrieval of prior cueing processes appears to be implicit, in that participants have no conscious recall of where the cue had been presented. Furthermore, when RT to detect targets is the dependent measure, long-term inhibition can only be detected in optimal face processing circumstances, i.e., when faces are encoded and retrieved via presentation to the LVF. The work has also demonstrated that there may also be upper and lower visual field asymmetries. That is, inhibition is more likely to be retrieved when faces are presented in the upper visual field. Indeed the most robust effects (in static conditions) are observed when left and upper biases are combined in the upper-left quadrant of the display. Finally, this study has attempted for the first time to investigate the time course of retrieval of prior inhibitory states. Clearly our conclusions concerning, for example the time-course of retrieval of inhibition, are tentative at this stage, and certainly need further study to confirm and extend these observations. Of particular importance, the relationship between the long-term and short-term cueing effects need to be identified. We believe our studies reflect long-term IOR effects, but acknowledge that this remains an open issue.

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Appendix A: RT Results not involving cueing validity (inhibition) effects.

The analysis showed a main effect of vertical target location, reaction times being significantly faster towards the top half of the display than to the bottom half, $F(1,30)=30.8$, $p<.0001$. A similar main effect was found for horizontal target location, reactions towards the right side being generally faster than towards the left, $F(1,30)=27.3$, $p<.0001$. Vertical and horizontal target locations interacted to a statistically significant extent ($F(1,30)=10.9$, $p<.01$), mainly because RT was fastest for targets in the top-right quadrant (see Table 1). These results may reflect the response bias of our right-handed participants.

An interaction between face motion and horizontal target location was found, which suggested that reactions to a face in the right visual hemi-field could be made even more quickly when faces moved within this hemi-field $F(1,30)=5.2$, $p<.05$ (see Table 1). Face Motion (static/move) also showed an interaction with duration of the retrieval cue and horizontal target location ($F(1,30)=6.1$, $p<.05$). RTs were generally slower to the left than to the right, but for a long retrieval cue duration RT for moved faces were faster than for static ones on the right, while they were not different in the other conditions (see Table 1). Finally, Face Motion showed an interaction with duration of the retrieval cue and vertical target location ($F(1,30)=4.6$, $p<.05$). RTs were generally slower to the bottom than to the top, but this effect was most pronounced for static faces at a long retrieval cue duration.